Without waking you, many of the more than 600 muscles in your body are still working to keep you alive. The muscles in your heart are contracting to pump blood throughout your body. Your chest muscles are working to help move air in and out of your lungs. Perhaps last night's dinner is still being moved through your digestive system by muscles.

Most muscles, or muscle tissue, are composed of muscle fibers that run beside, or parallel to, one another and are held together in bundles of connective tissue. Each muscle fiber is actually a single cylinder-shaped cell. Recall from Chapter 1 that a tissue is a group of similar cells that work together to perform a specific function. In the case of muscle tissue, that function is to contract, or shorten.

Types of Muscles

In the human body, there are three types of muscle tissue: skeletal muscle, smooth muscle, and cardiac muscle. Each type of muscle tissue has a characteristic structure and function. The muscle tissue that attaches to and moves bones is called **skeletal muscle.** This is an appropriate name for this type of muscle tissue because it is associated with the bones of the body, or the skeletal system. By contracting, skeletal muscle causes your arms, legs, head, and other body parts to move.

Figure 2–10 *Like an American toad and an impala, a human can perform many types of movements as a result of the actions of muscles pulling on bones.*

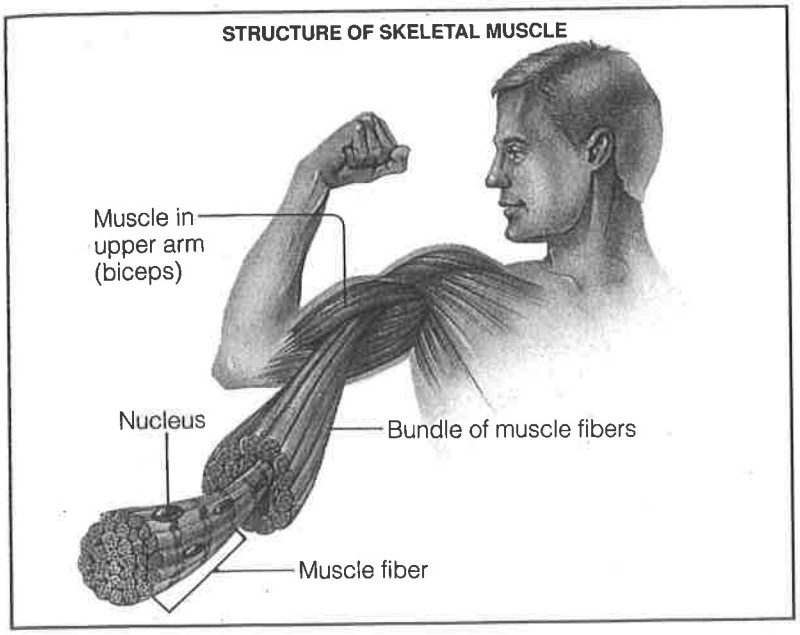


Figure 2–11 *Muscle tissue is composed of muscle fibers that run parallel to one another and are held together in bundles of connective tissue. The biceps muscle, which is located in the upper arm, is an example of skeletal muscle tissue. Why is the biceps classified as a skeletal muscle?*

If you were to look at skeletal muscle under a microscope, you would see that it is striated (STRIGH-ayt-ehd), or banded. For this reason, skeletal muscles are called striated muscles. Figure 2–12 on page 40 shows the bands associated with skeletal muscle. And because skeletal muscles move only when you want them to, they are also called voluntary muscles.

To appreciate how some of the voluntary (skeletal) muscles in your body work, think of the movements you make in order to write your name on a sheet of paper. The instant you want it to, your arm stretches out to pick up the paper and pencil. You grasp the pencil and lift it. Then you press the pencil down on the paper and move your hand to form the letters in your name. Your eyes move across the page as you write. To do all of this, you have to use more than 100 muscles. Now suppose you did this little task 100 times. Do you think the muscles in your hand would ache? Probably so. For although skeletal muscles react quickly when you want them to, they also tire quickly. Perhaps you might want to actually try this.

A second type of muscle tissue is called **smooth muscle.** Unlike skeletal muscle, smooth muscle does not have bands. Hence, its name is smooth. In general, smooth muscles can contract without your actively causing them to. Thus, smooth muscles are also called involuntary muscles. The involuntary

ACTIVITY DISCOVERING

Voluntary or Involuntary?

1. Blink your eyes three times.

2. Then try not to blink. Time how long you are able to keep yourself from blinking. Record your data.

3. Repeat step 2. Determine the average time you can keep from blinking.

How does your average time compare with that of your classmates? Are the eye muscles involved with blinking voluntary or involuntary muscles? Explain.

■ Using a mirror, observe what happens to your pupils in bright light and in dim light. Are the muscles that are involved in these actions voluntary or involuntary? How does the action of these muscles differ from those involved in blinking?

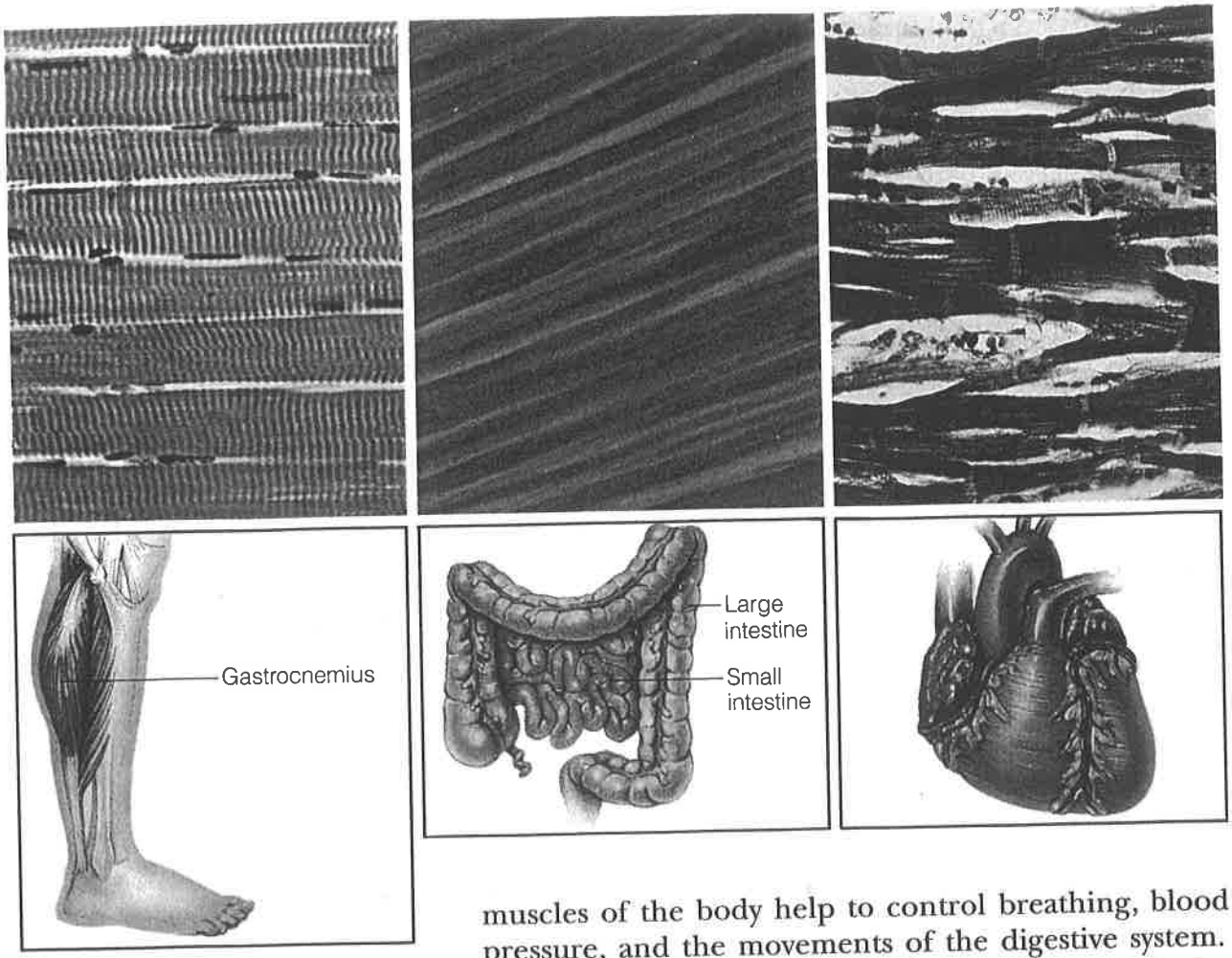


Figure 2–12 *There are three types of muscle tissue: skeletal muscle tissue (left), smooth muscle tissue (center), and cardiac muscle tissue (right). Where in the body are these muscle tissues found?*

muscles of the body help to control breathing, blood pressure, and the movements of the digestive system. Unlike skeletal muscles, smooth muscles react slowly and tire slowly. How might this be an advantage for smooth muscles?

A third type of muscle tissue, **cardiac muscle,** is found only in the heart. Branching out in many directions, cardiac muscle fibers weave a complex mesh. The contractions of these muscle fibers make the heart beat. Like smooth muscles, cardiac muscles are involuntary. Heart muscle, as you may have guessed, does not tire.

Action of Skeletal Muscles

As you have learned, muscles do work only by contracting, or shortening. In order for skeletal muscles to bring about any kind of movement, the action of two muscles or two groups of muscles is needed. Put another way, muscles always work in pairs.

Activity Bank

Under Tension, p. 248

For example, if you were to raise your lower arm at the elbow, you would notice that a bulge appears in the front of your upper arm. This bulge is caused by the contraction of a muscle called the biceps. At the same time the biceps contracts, a muscle called the triceps, which is located at the back of your upper arm, relaxes. Now suppose you wanted to straighten your arm. To perform this simple feat, your triceps would have to contract and your biceps would have to relax at the same time. Figure 2–13 shows how these two muscles (the biceps and the triceps) work together to help you bend and straighten your arm.

The mechanism by which muscles contract is actually a bit more complex than what you have just read. For it is not only muscles that are involved in this action. Nerve tissue is also involved. Skeletal

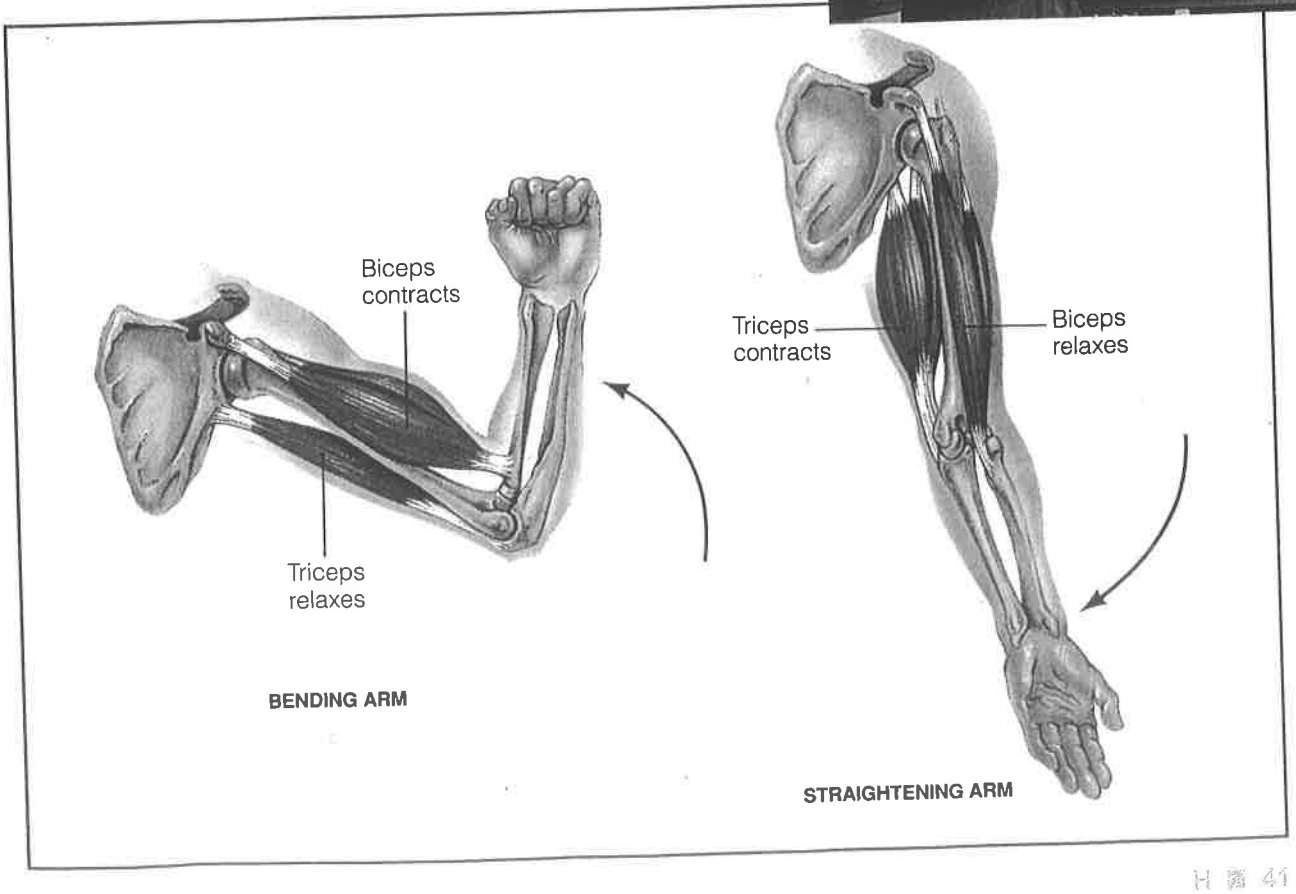


Figure 2–13 *When you "make a muscle," the biceps muscle and the triceps muscle work together. According to the diagram, which muscle relaxes when the arm is bent? When the arm is straightened?*

ACTIVITY DISCOVERING

Muscle Action

1. Obtain a spring-type clothespin.

2. Count how many times you can click the clothespin in two minutes using your right hand. Record the information.

3. Rest for one minute and repeat step 2. Then rest for another minute and repeat step 2 again. Determine the average number of clicks for the right hand.

4. Using your left hand, repeat steps 2 and 3.

Was there a difference in the number of clicks per minute between the right and the left hand? Explain.

■ Why do you think you were able to click the clothespin faster at the beginning of the investigation than you were near the end?

muscles, you see, contract only when they receive a message from a nerve to do so. The nerves carry messages from the brain and spinal cord to the muscles, signaling them to contract.

You may be surprised to learn that there is no such thing as a weak or strong contraction of a muscle fiber. When a fiber receives a message to contract, it contracts completely or not at all. The strength of a muscle contraction is determined by the number of fibers that receive the message to contract at the same time. Strong muscle contractions, such as those that are involved in hitting a ball with a bat, require the contractions of more muscle fibers than would be needed to open a textbook.

2–2 Section Review

1. List the three types of muscle tissue.
2. Compare the structure of a voluntary muscle and an involuntary muscle.
3. Describe how muscles work in pairs.

Critical Thinking—*You and Your World*

4. If your biceps were paralyzed, what movement would you be unable to make?

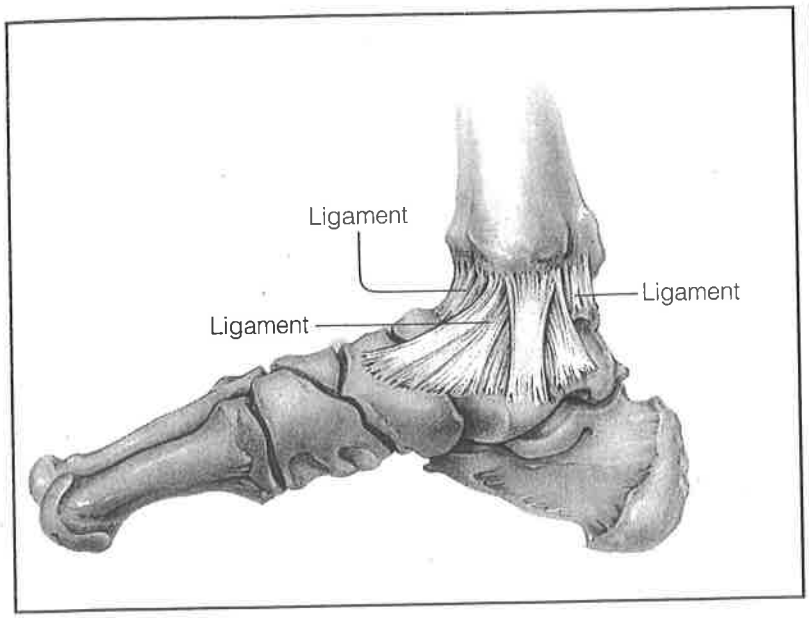
Guide for Reading

Focus on this question as you read.

▶ *What are the three most common injuries involving the skeletal and muscular systems?*

2–3 Injuries to the Skeletal and Muscular Systems

Supported by bone and activated by muscle, your body can perform a wide range of movement—from hammering a nail to blinking an eye. The same foot that can stand on tiptoe can kick a soccer ball. The same hand that can pat a puppy's head can pound a desk. Based on these activities, you may be inclined to think that the bones and muscles—components of the skeletal and muscular systems—are invincible. But are they?



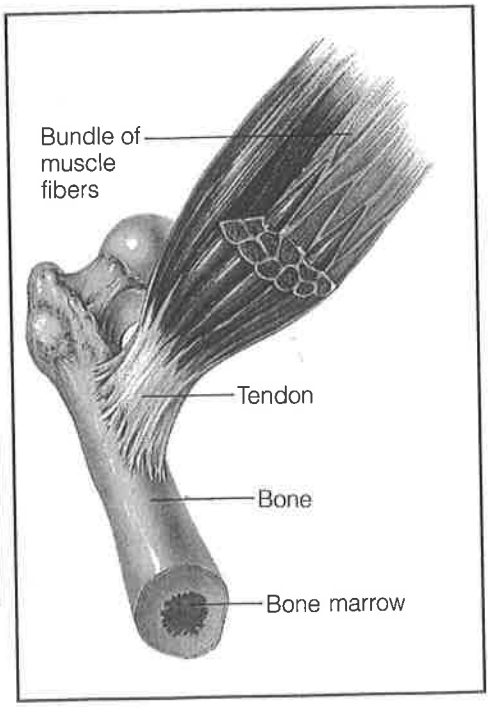


Figure 2–14 *In a sprain, tendons or ligaments get torn or pulled beyond their normal reaching range. What structures are joined by tendons? Ligaments?*

Although bones and muscles are able to withstand quite a bit of wear and tear, they are vulnerable to injuries. **Some injuries that affect the skeletal and muscular systems are sprains, fractures, and dislocations.** In a **sprain,** the ligaments or tendons, such as those in the ankle, get torn or pulled beyond their normal stretching range. Although a sprained ankle may be painful, you can move your ankle because the injured ligaments and tendons are still able to function.

The most common type of injury to the skeletal system is a **fracture.** A fracture is a break in a bone. Fortunately, because a bone is made up of living tissue, it begins to heal almost as soon as the fracture occurs. A bone's self-healing process takes place in an orderly sequence of events. First the broken blood vessels at the fracture area form a blood clot. In a few days, minerals from the sharp ends of the broken bone are absorbed into the bloodstream. At the same time, fibers of connective tissue grow out of the bone to hold the fractured ends together with a type of bone-making "glue." In as short a time as a few weeks, some bones have healed so well that even X-rays cannot show where the fracture occurred.

Sometimes a blow to the skeleton causes a bone to be forced out of its joint. This type of injury is called a **dislocation.** Dislocations can be serious, but fortunately they can be corrected easily in most cases.

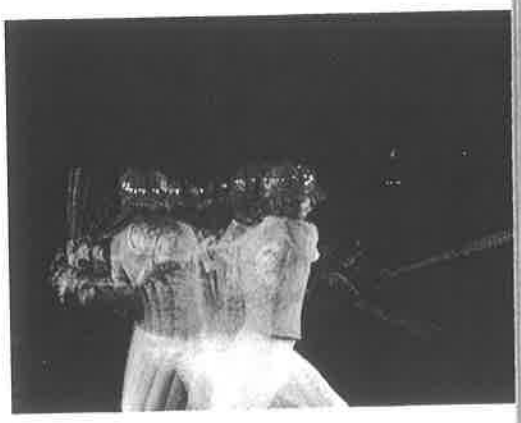


Figure 2–15 *Although the skeletal and muscular systems are able to withstand a lot of wear and tear, they are vulnerable to injuries. What injuries might this baseball player develop from swinging at the ball too hard?*

Figure 2–16 *In the X-ray of a lower leg (left), you can see breaks in the tibia and fibula. The X-ray of a hip (right) shows how a bone can be forced out of its joint in a dislocation. What is another name for a break in a bone?*

The dislocated bone can be pushed back into position by a doctor.

As scientists learn more about the skeletal and muscular systems, they continue to develop new techniques for repairing or replacing damaged parts. One technique for healing fractures involves applying weak electrical currents to broken bones. In most cases, electricity causes the bones to heal more quickly. Sometimes badly damaged joints, such as the hip or the knee, can be replaced with artificial joints made of plastics or metal.

2–3 Section Review

1. List the three most common injuries to the skeletal and muscular systems.
2. Compare a sprain and a fracture.
3. Describe the repair of a broken bone.
4. Why do you think a sprained ankle is so painful?

Connection—*Chemistry*

5. Artificial hips are generally made of plastics and alloys (substances that are mixtures of metals), which are lightweight and do not react with other materials. Explain why these characteristics make plastics and alloys useful in the replacement of human body parts.